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RECOMMENDED SHORT-TERM ATC IMPROVEMENTS FOR HELICOPTERS

VOLUME III

OPERATIONAL DESCRIPTION OF EXPERIMENTAL LORAN-C FLIGHT FOLLOWING (LOFF) IN THE HOUSTON AREA

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Task Report

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16. Abstract

The recommended Short Term ATC Improvements for Helicopters are documented in three volumes, i.e.:

- Vol. I is a summary report of all improvements studied. Improvements are categorized as to those that can be recommended for immediate operational consideration or use and those that require limited short term simulation or test.

  The recommendations for immediate use include: (1) Helicopter ATC training material, (2) Operational Description of LOFF, (3) Recommendations concerning military training routes and (4) Survey data for use in Gulf communications and route structure planning.

  The recommendations for short term simulation include: (1) Dual waypoint holding patterns, (2) other holding patterns and (3) shortened entry procedures for intercepting final approach path.
- Vol. II is the complete training material for helicopter ATC. It contains major sections on Helicopter Capabilities and Limitations, on Helicopter Navigation and on Helicopter Control Procedures.
- Vol. III is the complete Operational Description of the Experimental Loran Flight Following (LOFF) in the Houston Area. It describes both airborne and ground components and states the objectives that are being sought in the experiment.

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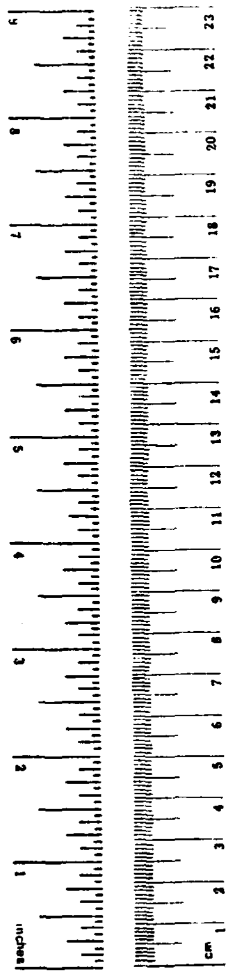
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

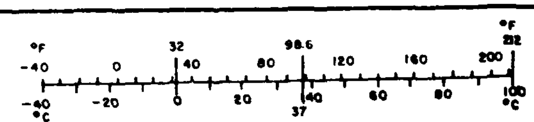
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



OPERATIONAL CONCEPTS FOR LORAN

FLIGHT FOLLOWING IN THE HOUSTON AREA

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I wish to express my sincerest gratitude to all the above stated organizations and look forward to continued association with them during my continued involvement in the helicopter program.

Raymond J. Hilton
ATC Helicopter Program Mgr.

OPERATIONAL DESCRIPTION OF EXPERIMENTAL LORAN FLIGHT FOLLOWING (LOFF) IN THE HOUSTON AREA

Background.

The present air traffic control system is based on the use of primary and secondarv radar, as well as VHF communications. Unfortunately these three systems are subject to line-of-sight propagation; their signals are cut off by any intervening obstructions, including the curvature of the earth itself.

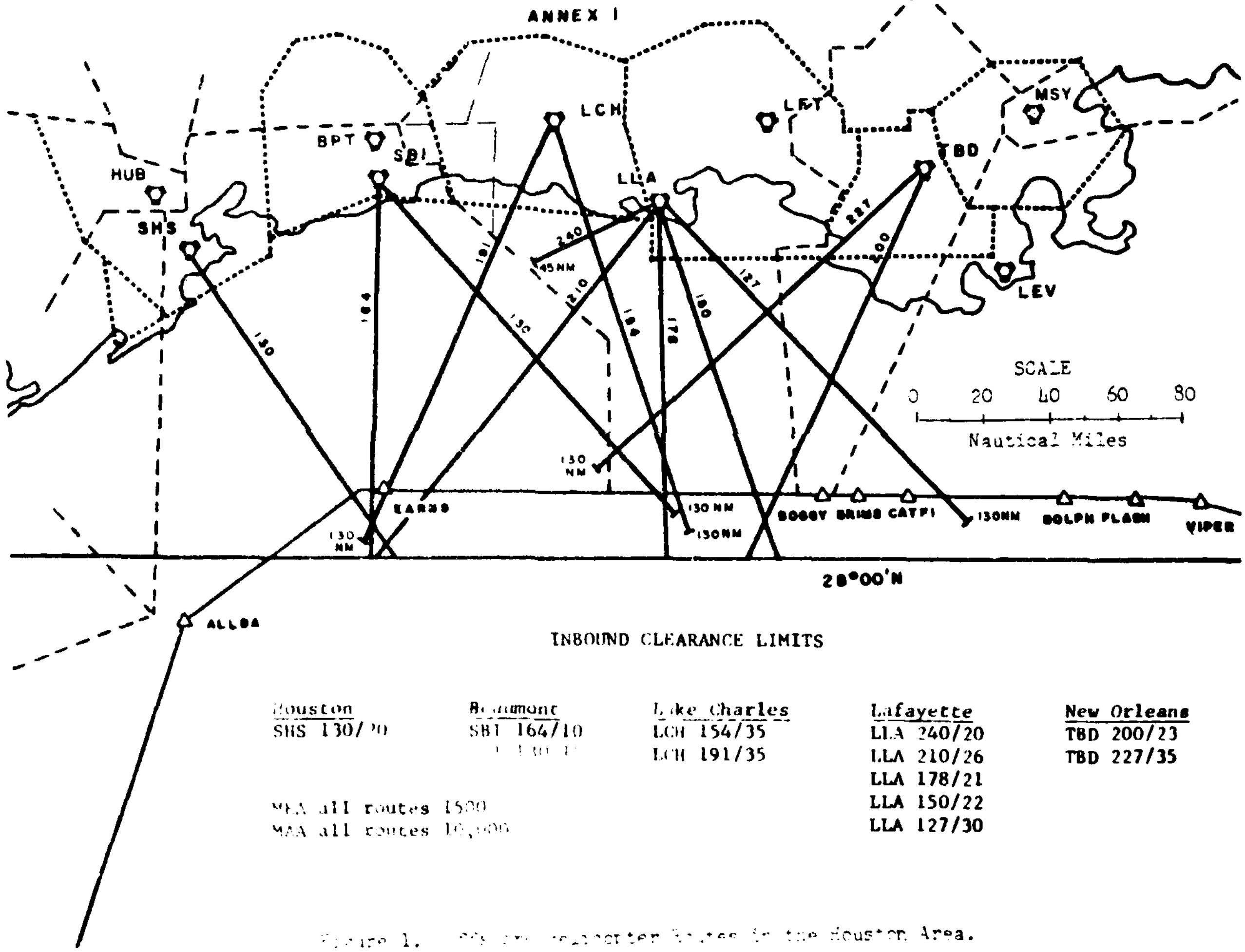
This limitation is particularly apparent in the control of offshore helicopter traffic in the Gulf of Mexico area south of the Louisiana/Texas coastline. In this area helicopters seldom operate above 5000 feet and are usually much lower. This area is shown in Figure 1. Beyond 30 miles from the coastline, much of the helicopter traffic is beyond or below ATC radar and communications coverage.

However, as shown in Figure 2, the area is blanketed by LORAN C coverage. LORAN C is a long-range hyperbolic navigation system which is being used by a growing number of offshore helicopter operators in the Gulf area.

The LOFF System

Operating Concept. The FAA is developing an experimental system which will generate a pictorial display of traffic operating in offshore airspace beyond radar cover. The system is called LOFF, which stands for LORAN Flight Following. In this concept, each participating aircraft will transmit the position data received by its LORAN C navigation receiver, to the ATC facility (in this case the Houston Center). Each message will also contain the aircraft identification code and assigned altitude. The digital message will be processed by a special computer to generate an alphanumeruc/graphic display which will resemble in many respects the automated displays produced by the NAS computer.

OFFSHORE HELICOPTER ROUTES
ANNEX I



INBOUND CLEARANCE LIMITS

Houston	Beaumont	Lake Charles	Lafayette	New Orleans
SHS 130/20	SBI 164/10	LCH 154/35	LLA 240/20	TBD 200/23
	[illegible]	LCH 191/35	LLA 210/26	TBD 227/35
			LLA 178/21	
			LLA 150/22	
			LLA 127/30	

MEA all routes 1500
MAA all routes 10,000

Figure 1. Offshore Helicopter Routes in the Houston Area.

CHG 2
3/20/80

SOUTH EAST USA CHAIN – GRI 7980

Diagram showing suggested secondaries to be used for obtaining the best fix and the best position line in different parts of the Ground Wave coverage area.

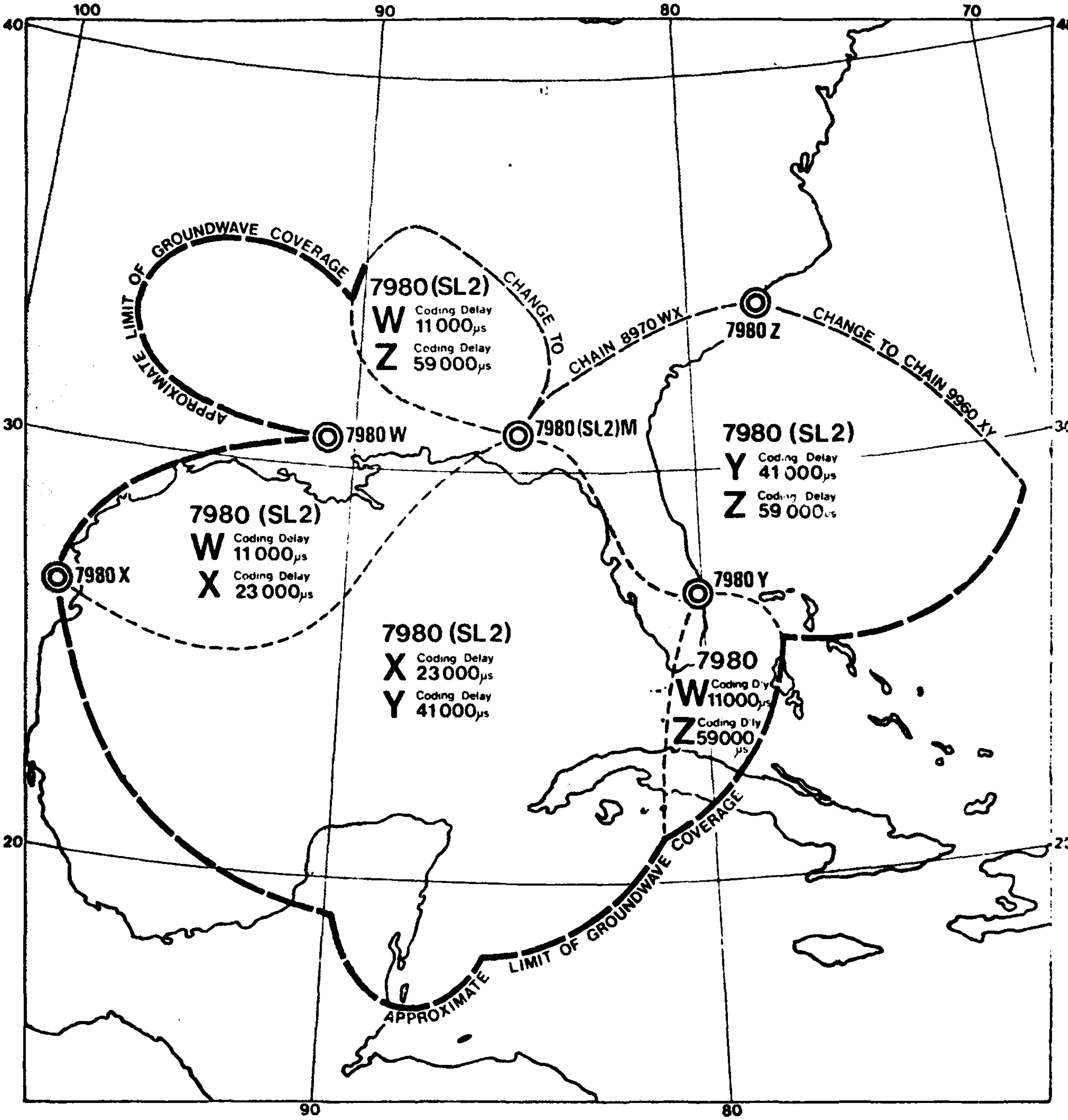


Figure 2. LORAN C Coverage in Gulf of Mexico Area

Figure 3 is a simplified diagram of the experimental LOFF System, which is being planned as a stand-alone system, independent of the NAS computer and the NAS displays. The display will not be used for the separation of traffic, but only as an enhancement to non-radar control operations. Separation standards based on procedural (non-radar) control will continue to be used.

Operating Environment. Initially the system environment shown in Figure 1 will be operated as a single sector of the Houston FIR. The sector will include the offshore airspace down to 28° N latitude, and from 1200 MSL (the floor of controlled airspace) up to 10,000 MSL. Later, if helicopter IFR traffic increases to the point where more than one sector is necessary, this airspace will be divided into east and west sectors.

The approved routes shown in Figure 1 are based on selected VOR radials, spaced at least 15° apart; VOR/DME navigation is used out to 40 nm from the VOR; beyond that distance, navigation is based on LORAN C, along the extended radial courses. All distances along each course are referenced from the respective VOR facility.

Route widths are 4 nm on either side of the centerline. Each route extends within 20 nm of the destination normally used. About 20-25 nm from the destination platform, the outbound helicopter leaves the designated radial course and filies a direct course to the destination waypoint. Airborne radar (ARA) is used to supplement LORAN-C for approach guidance. The pilot reports to ATC when cancelling IFR or when leaving controlled airspace at 1200 MSL.*

In returning from an offshore platform, the inbournd helicopter follows the same route in the opposite direction.

* Current actions being considered by the FAA may alter these procedures.

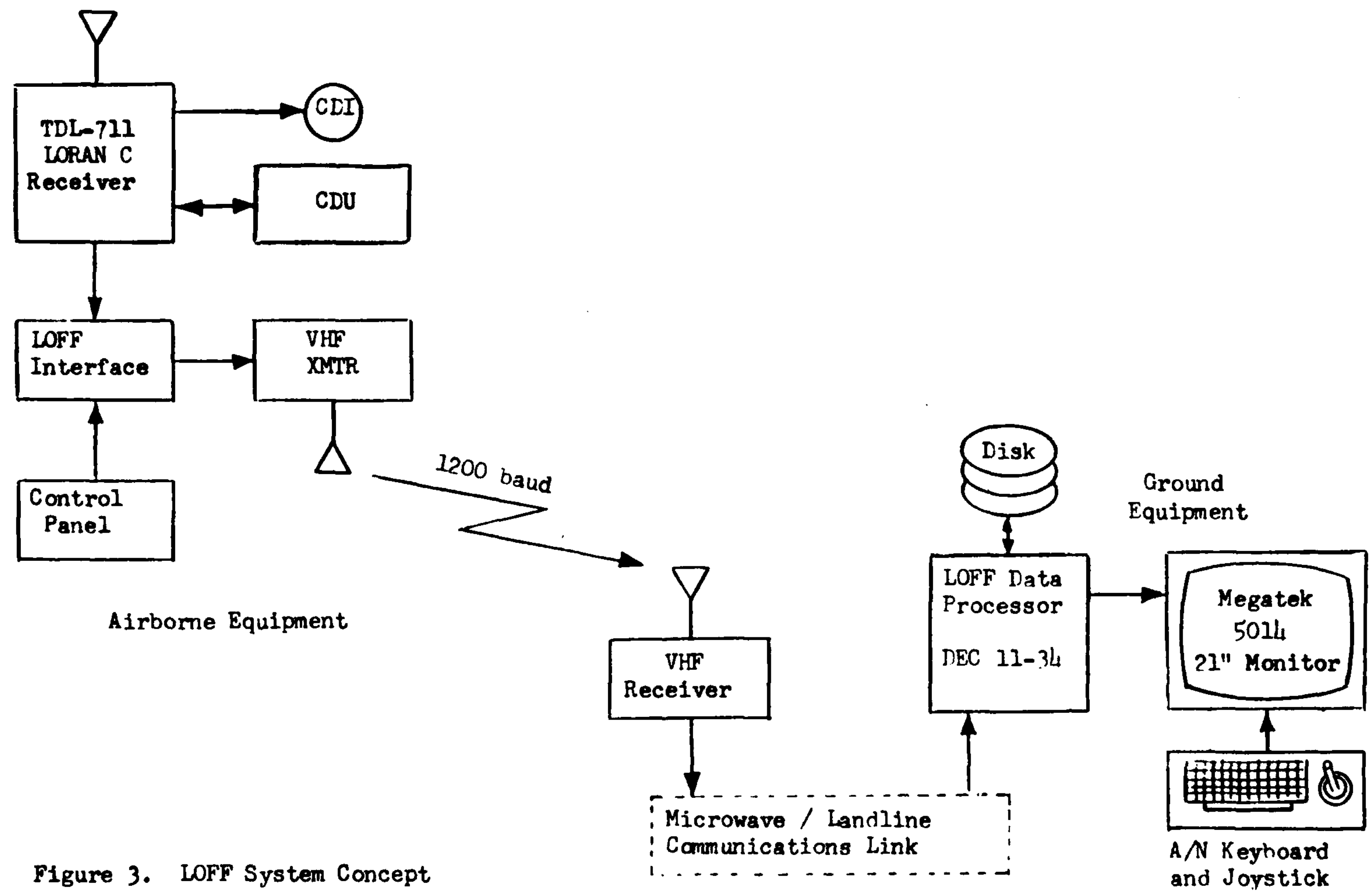


Figure 3. LOFF System Concept

System Objectives

Enhancement of Procedural Control. Although it is intended that offshore traffic will continue to be controlled using procedural separation standards, the use of LOFF as a visual aid should enable controllers to make optimum use of such standards by being able to exploit situations which might not be immediately obvious from scanning the flight progress strips alone.

Reduction of Controller Workload. LOFF will provide the controller with a graphic (CRT) display of aircraft identity, altitude, and position, along with the route structure being used. This will enable the controller to analyze the traffic situation much more quickly, and with less mental effort, than from tabular information on the flight progress strips. The time savings per aircraft can be used for improved planning, or for greater sector capacity.

Increased Flexibility. LOFF will provide the controller with a new degree of flexibility by being able to call up and display additional routes for off-airway traffic. These routes can be displayed on an as-needed basis, and erased instantly when not needed. This capability will be especially useful in handling special flights such as Medevac or Coast Guard operations.

Increased Safety. By being able to display the intended routes as well as the targets, LOFF will enable controllers to detect any navigational errors before they become critical. Other safety advantages are the ability to expedite medevac missions on direct routes, and to enhance search and rescue missions by the ability to record and recall the last reported position of an aircraft in distress and to guide other aircraft to the same position.

Assurance of Navigation System Integrity. A secondary objective of the program will be to monitor the integrity of the LORAN C navigation system. Stationary LORAN C receivers will be installed at various locations to feed TD (time-difference) data to the LOFF computer. Here the data will be stored for later analysis of the performance of the navigation system.

Airborne Components

Navigation Receiver. The initial LOFF system will use LORAN C data from the TDL-711 LORAN C receiver in the aircraft. (Over 100 offshore helicopters are already equipped with the TDL-711 system). Outputs are in the form of time differences (TD's). Two intersecting TD's constitute a LORAN fix.

Interface Box. The LORAN time difference information is fed to an interface box which stores the aircraft identification code and the latest LORAN C time difference data, for automatic transmission over one of the aircraft VHF transmitters. A digital message is sent whenever a trigger pulse is received from a clock circuit in the interface box. The message repetition rate is controllable as described below. Each message requires approximately ¼ second to transmit.

Control Panel. The pilot control panel includes the controls shown in Figure 4, although the actual arrangement may vary from the layout shown. The panel includes a 4-position switch which switches the output to either, neither, or both of the VHF transmitters in the aircraft.

The control panel includes four 10-digit (0-9) code switches for setting in the LOFF code assigned by ATC. This code is comprised of a 3-digit identification which coincides with the computer identification (CID) of the flight plan. The fourth digit encodes the assigned message repetition rate, as shown in Figure 8.

The panel includes three other 10-position switches which may be used for manually setting in the assigned altitude (in hundreds of feet); in case if it is decided not to use manually input altitude, these code wheels may be used for other types of A/G data. There is a future option to utilize

CODE SETTING FOR MESSAGE REPETITION RATE	BASIC INTERVAL, SECONDS	RANDOM RANGE OF INTERVALS, SECONDS
0	*	*
1	15	13.5 - 16.5
2	30	27 - 33
3	45	40.5 - 49.5
4	60	54 - 66
5	90	81 - 99
6	120	108 - 132
7	180	165 - 195
8	240	225 - 255
9	300	270 - 330

* = Manual reporting mode only

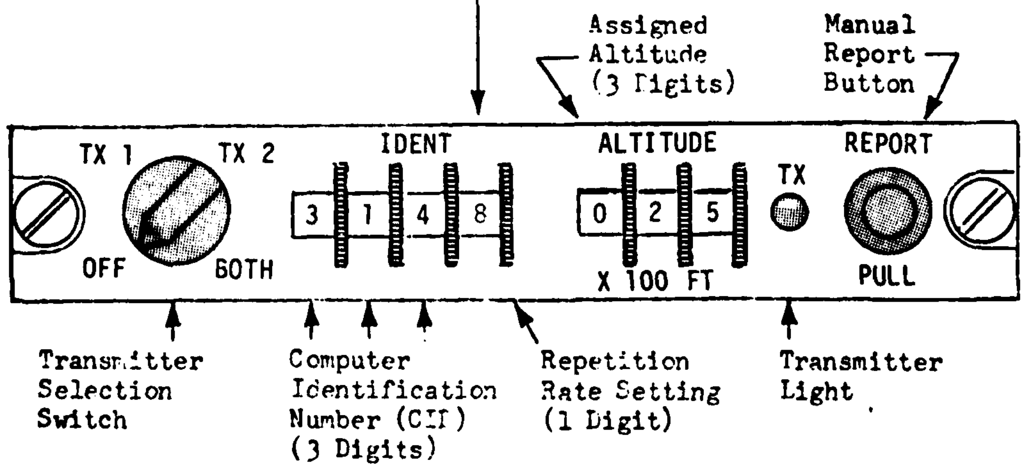


Figure 4 Functional Layout of Avionics Control Panel, with List of Message Repetition Rates Above

automatically input altitude data (from aircraft equipped with altimeter transducers).

The control panel includes a manual button which, when operated by the pilot, triggers the transmitter to send three complete messages at 2-second intervals.

Communications Links

Offshore IFR helicopters carry two VHF transceivers for voice communications on company and ATC channels. For economy, the LOFF system will use one of these units to transmit digital messages over a VHF voice channel. The digital LOFF messages will go from the helicopter via VHF to a remote VHF outlet, thence via microwave links to a shore station, thence via land lines to the LOFF computer in the Houston Center. For this purpose, the Southwest Region of the FAA is planning for the installation of several remote VHF outlets on strategically located offshore platforms, plus some improved and additional RGAG facilities on shore.

The offshore FAA facilities will be connected to shore facilities via microwave links owned by the petroleum industry; the shore facilities will be linked to the Houston Center via land lines. Completion of this network will not only provide the necessary channels for LOFF transmission, but will initiate the much-needed capability for direct ATC air/ground communication between the Houston Center and helicopters operating beyond the harizon, in the offshore area.

Ground Equipment

Data Processor. The LOFF will be designed as a stand-alone system, not connected to the NAS Computer. It will utilize a DEC 11-34 minicomputer with disk storage, to decode the digital information received from the various aircraft, and present this on a CRT Display. The minicomputer will also generate, from digitally-stored data, a background map showing relevant routes, airports, heliports, and landing platforms.

Control Panel. The display control will include a standard alphanumeric keyboard, plus a joystick which will move an electronic cursor across the entire screen to designate geographic targets on the traffic display or to call up data or commands on the scratch-pad area. The various command capabilities are described later in this report.

Display. The display will be presented on a Megatek 5014 21" CRT Monitor. The display format and capabilities are described in detail, in a later section of this report.

Operational Considerations.

Design Goal. An important consideration in the design of the LOFF system is for the resulting systems to do as much as possible for the controller, with the least amount of controller workload associated in the operation of the equipment. To this end, the actions required to operate the display will be minimized; for example the controller will be able to call up a display command either by placing the cursor on top of the command mnemonic on the scratch pad area of the display, or by typing in the 2-letter mnemonic on the keyboard. Also the display symbology itself will duplicate, wherever possible, that used in the NAS system, in order to minimize training time, and to avoid confusion when transitioning to and from other sectors.

Message Repetition Rate. The initial LOFF avionics will provide for up to ten different message repetition rates which can be assigned by ATC

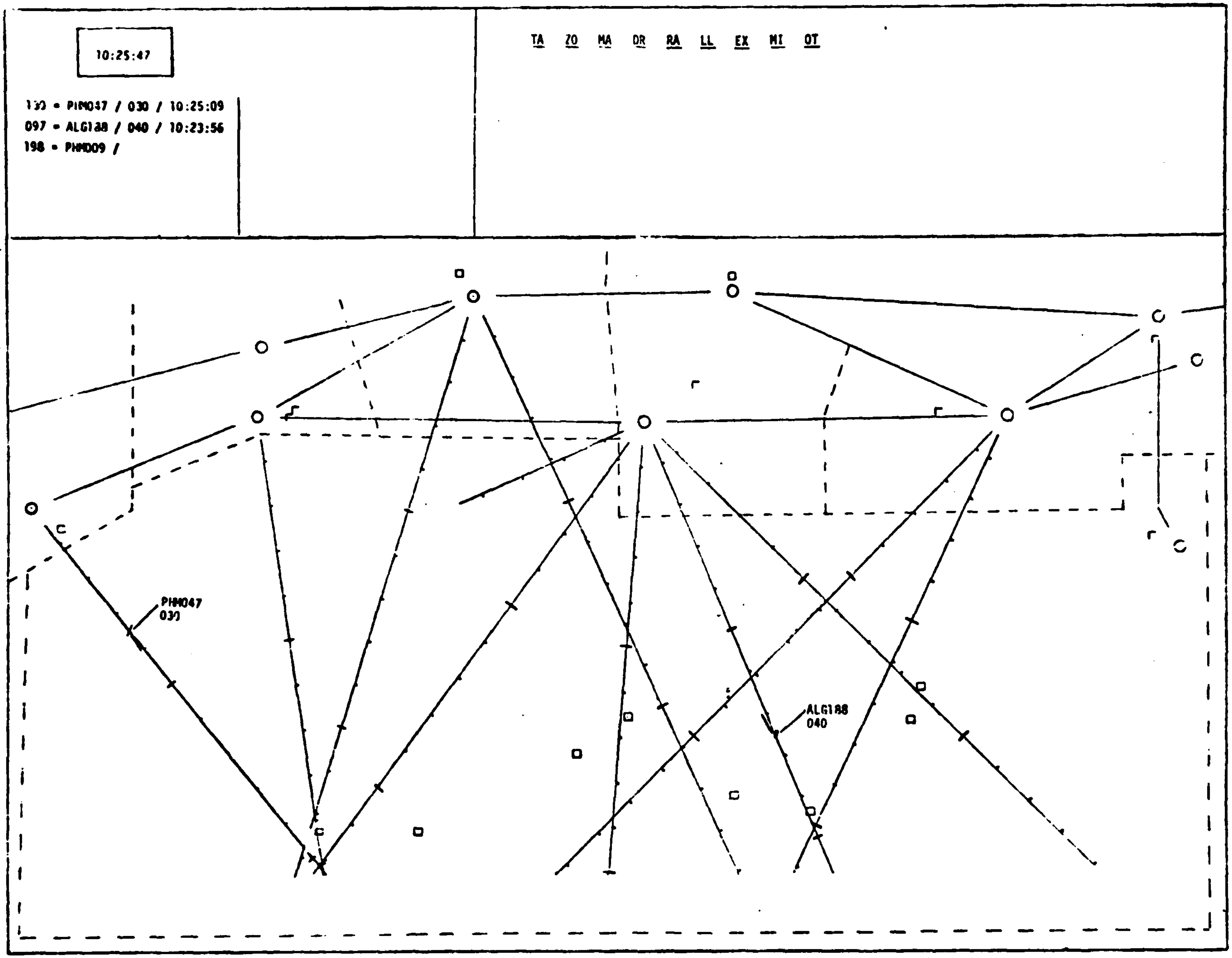


FIGURE 5 TYPICAL LOFF DISPLAY

and set in by the pilot. The minimum basic interval will be 15 seconds, the maximum 300 seconds. To reduce garble, intervals will be varied on a random basis as shown in Figure 4. Variables which affect the choice of the repetition rate setting, in any given situation, are summarized below:

- A higher rate would tend to be desirable for faster aircraft in order to decrease the distance between successive reports. It would also enable the tracking system to catch up with the actual position of aircraft sooner, whenever the aircraft made a radical change in heading or speed.

- A lower rate would tend to reduce the possibility of garbling (message overlap), but would increase the distance between attempted reports, at any given ground speed. A low rate might still be adequate in areas of low traffic density.

Code Selection. When a flight plan is entered into the NAS computer, it is automatically assigned a discrete 3-digit computer identification (CID) number. This number is printed on all flight progress strips for that flight.

When the proposed departure strip is posted, the controller types the CID into the LOFF computer, together with the aircraft identification number (AID). This data is displayed in the scratch pad area of the display. Example: 482 = PHL 190

The CID forms the first 3 digits of the LOFF Code which is assigned to the pilot. The fourth digit of the LOFF code represents the desired message repetition rate for the LOFF messages. Example: CID number 482, Desired rep. rate 1, Assigned LOFF Code = 4821

The pilot sets this number into the LOFF control panel (see Figure 4).

When a LOFF transmission from this aircraft is received at the ATC facility, the LOFF computer decodes the first digits of the LOFF code (482), associates it with the AID (PHL 190), and prints out the latter identification in the target block for this target.

Special Phraseology. The word LOFF will be added in the Remarks Section of the flight plan to denote that the aircraft is LOFF-equipped.

The phraseology LOFF CODE, followed by four digits, will be used whenever a LOFF code is assigned or changed. (Example: LOFF CODE 4307).

Display Characteristics.

Background Map. The digitally stored background map will cover the geographic area from 26° to 30° 30'N, and 87° 30 to 98° W. However, it is anticipated that during the initial operating period, the map scale will be enlarged, to cover only the area from 27° 45' to 30° 15' N, and 90° to 95°W.

The minimum display will include approved routes as solid lines, sector boundaries as dashed lines, and VOR's as circles. The approved helicopter routes will be marked off in 10 NM increments referenced from the VOR/DME station. Heavier crossmarks will be used at 50 NM increments. Major oil platforms and heliports will be shown as squares.

Aircraft Targets. The aircraft position will be represented by a target symbol. An actively tracked LOFF target will be shown as a slash mark (/). A target in the coast mode will be shown as a pound sign (#).

Each target will be connected to an alphanumeric target block by a short leader line. Normally the target block will be shown northeast (above and to the right) of the target symbol. However the controller can change the orientation of any individual target block, in order to avoid overlaps, to the northwest, southwest, or southeast positions.

The top line of the target block will show the aircraft identification (AID); for example, PHL 190.

However if the LOFF computer receives an aircraft position report with a computer identification number (CID) which is not associated with any AID stored in the system, the top line of the target block will show XXX plus the CID; for example XXX 489.

The second line of the target data block will show the assigned altitude as manually entered by the pilot.

A predicted vector line can be added to the target display at the discretion of the controller. In this case the tracking system will cause a line to be projected ahead of each target to predict its position at the end of any number of minutes desired by the controller. For example a 10-minute projection will be useful in situations where a 10-minute longitudinal separation standard is being used.

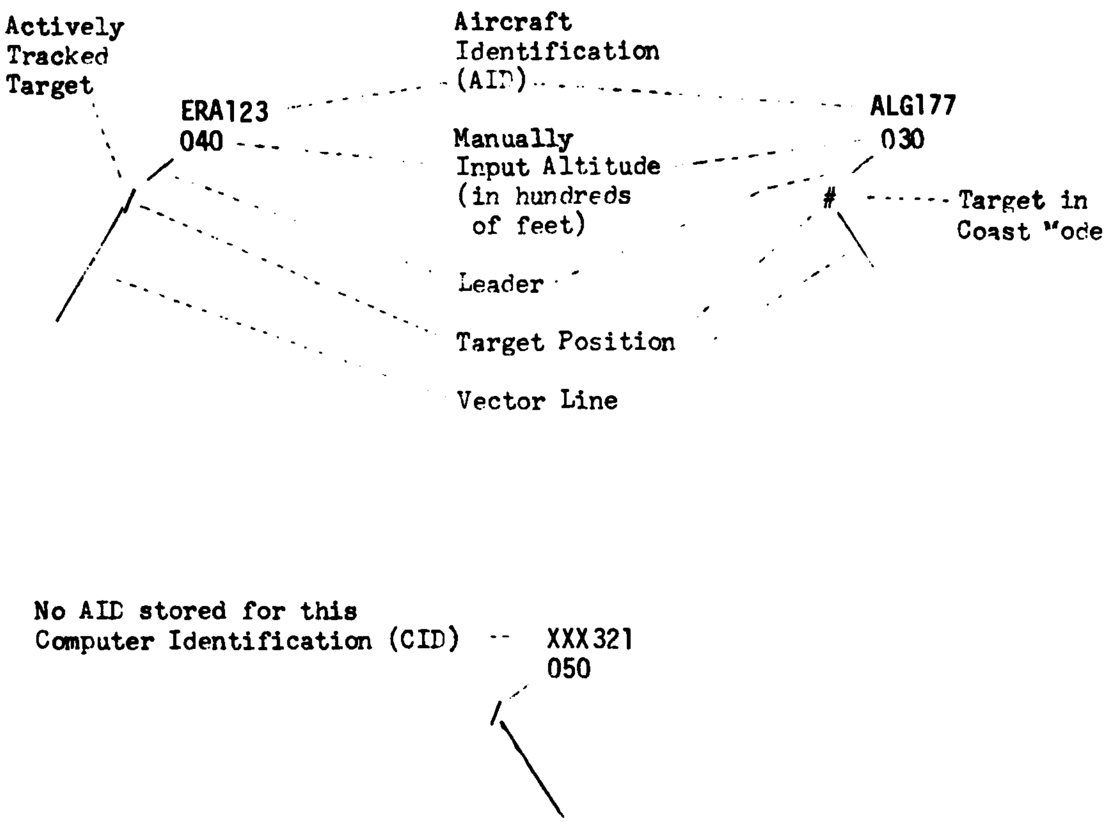


Figure 6. Target Format

Scratch-Pad Area. A horizontal slice of the display will be used as a scratch-pad area, for interactive control of the displayed information by the air traffic controller. The upper left hand corner of the scratch-pad area will show Zulu time in hours, minutes, and seconds. Immediately under this and extending to the right will be an area where the controller types in computer identification (CID) numbers of active or impending LOFF-equipped aircraft. He also connects each of these entries with the appropriate radio call sign of the aircraft (aircraft identification or AID). Example: 482 = PHL 190.

For each aircraft which is being actively tracked, the display will show the time of the last message received. Example: 482 = PHL 190/10:25:45.

This portion of the display will have room for two columns of such entries. If the entries overflow the space available, a wraparound procedure will be used for displaying the other entries as needed.

The right side of the scratch-pad area carries a list of mnemonic (abbreviated) display commands. Any command can be called up either by typing in its two-letter mnemonic, or by moving the cursor to this area on the scratch-pad surface, as described below.

Control Functions.

Table 1 lists the various command options, controller inputs, and functions.

TABLE 1 LOFF DISPLAY CONTROL FUNCTIONS

NOTE: r is carriage return

OPTION	COMPUTER OUTPUT TO DISPLAY	CONTROLLER INPUT TO COMPUTER	FUNCTIONS
TA (TARGET)	Comp ID = ?	268=PHM 311 r	Start Target Display 268 is CID PHM 311 is AID
		268=D r	Stop (drop) target display
		268=030 r	Put 030 into data block (assigned alt)
		268/NW r	Flip data block to new quadrant NE NW SE SW
ZO (ZOOM)	Center/NE corner?	Cursor at center at NE r	Will redraw...Zoom In
		(with cursor off map)	Will redraw...Zoom Out to next level
EX * (EXTRA)	Enter ID?	VE245 r	Display Platform VE 245
		7R9/D r	Drop heliport 7R9 from display
MA * (MARK)	POSN/SYMBOL/ REMARKS?	2921/9310/A/WC180 r	Enter Lat/Lon/symbol/Remarks, and will appear on display, with "WC180"
		LLA240045/B/WC180 r	Enter fix-radial-distance/ Symbol/remark and B will appear on display, with "WC180"
		Cursor to symbol, D r	Drop symbol from display
DR (DRAW)	Cursor at A?B?	Cursor to A r to B r	Draw line from "A" to "B", display (relative) bearing & distance in scratch-pad
		Cursor at B...D r	Drop segment from display
RA (RADIAL)	Fix-radial Dist?	LLA240045 r	Draw radial from VOR/DMD
		LLA240045/D r	Drop display of radial
LL * (LAT-LON)	Cursor?	Cursor at point r	Display L on map; readout lat/lon in pad
		Cursor at symbol..D r	Drop display of L

* Incorporate blink function for 3 seconds on display

MI (MILITARY)		no entry opposite state (on/off)	Display MIL route and area Drop display
OT (OTHER)	(Present new set of options)	**	**

** Software for additional options is now under development and will be covered later when details are available.

Single-Thread Description

The following description details the proposed use of the LOFF system for typical outbound and inbound flights along the existing offshore routes of the Houston Center. Interactions between pilot (P) and center controller (C) are listed.

P	C	OUTBOUND FLIGHT TO PLATFORM
●		At least 30 minutes before departure, pilot files flight plan with dispatcher, adds "LOFF" in remarks. Dispatcher phones flight plan to Flight Service Station (FSS), which enters flight plan into NAS computer. Computer prints proposed departure strips with CID, in tower, approach control, and Houston Center (LOFF sector).
	●	Controller posts proposed departure strip, associates CID (Computer identification) with AID (Aircraft Identification by typing into LOFF display.
●		Pilot calls tower for ATC clearance. Tower requests clearance from center.
	●	Controller issues enroute clearance, with LOFF code, to tower; tower relays to pilot.
●		Pilot enters LOFF code and assigned altitude into control panel. Tower clears aircraft for takeoff, enters departure time into NAS computer, which prints enroute strip for LOFF sector and for departure control.
	●	Controller posts enroute strip.
		Tower tells pilot to contact departure control, who provides separation within terminal area. As aircraft approaches boundary of offshore sector, departure control tells pilot to contact center.
●		Pilot activates LOFF, contacts LOFF controller. Target appears on LOFF display in Center. (Continued on next page).

P	C	
		Target appears on LOFF display.
	●	Controller verifies target identity and altitude.
●		Pilot uses manual button for identity, verifies altitude.
	●	*As necessary, controller revises clearance or requests change in repetition rate.
●		Pilot changes LOFF frequency as necessary, in order to stay in contact with VHF outlets enroute.
●		*25 miles from destination platform, pilot requests descent clearance.
	●	*Controller issues cruise clearance to platform, requests pilot to report cancelling IFR or leaving controlled airspace.
●		*Pilot cancels IFR or reports leaving controlled airspace.
●		Pilot lands and turns off LOFF.
	●	When LOFF target goes into coast mode (#), controller drops target.

INBOUND FLIGHT FROM PLATFORM

●		At least 30 minutes before takeoff, pilot files flight plan (adding LOFF in remarks) with dispatcher, who phones flight plan to FSS, who enters flight plan into NAS computer. (In many cases this is all done before pilot starts on outbound trip). Computer prints proposed departure strip with CID, at LOFF sector.
	●	Controller posts proposed departure strip, associates CID with AID by typing into LOFF display.
●		*Ten minutes before takeoff, pilot calls for clearance.
	●	*Controller clears aircraft to approach control boundary, issues LOFF code and VIFNO time.

(Continued on next page)

*When direct pilot/controller communication is not possible, messages will be relayed over company channels.

P	C	
●		*Pilot enters LOFF code and assigned altitude in control panel, turns on LOFF, takes off, and reports departure time. Target appears on LOFF display in center.
	●	Departure time entered into NAS computer, which prints enroute strip.
	●	*As necessary, controller revises clearance or LOFF repetition rate.
●		Pilot changes LOFF frequency as necessary to stay in contact with VHF outlets enroute.
	●	*Five minutes before aircraft reaches approach control sector boundary, controller tells pilot to change to approach control frequency.
●		Pilot contacts approach control, turns off LOFF when leaving offshore sector.
	●	When LOFF target changes to coast mode (#) controller drops target.

* - See footnote on preceding page.

Non-Standard Routes

For aircraft flying other radial, offset parallel, or direct routes (as for example, a Medevac or USCG patrol mission) the controller can draw the intended route on the display, using either the Radial (RA) or Draw (DR) command options listed in Table 1. Placing the intended route on the display enables the controller to visualize its relationship, including lateral spacing or crossing points, with other routes and sector boundaries. When no longer needed, any segment of the route can be erased instantly, using the Drop (D) command.

Non-Equipped Aircraft

At the discretion of the LOFF sector controller, a non-LOFF-equipped aircraft can be displayed as a non-tracked (coast) target, to serve as a reminder of its presence in the traffic situation. In this case, the target is entered at a reported or estimated position, heading, and speed. Additional aircraft position reports are requested for updating the target position, particularly at fixes where the aircraft will change course. The target will appear as a coast (#) target until it runs off, or is dropped from, the display.

The capability of the LOFF system to display controllable moving targets can be used in the dynamic simulation (DYSIM) of various traffic scenarios for training controllers in off-shore ATC operations.

Non-Receipt of Position Reports

If no reports are received from an aircraft during some predetermined interval, the tracking system will update the target position in a coast mode, along the computed track. In this case the target symbol will change to a pound sign (#) to indicate that the target is in a coast mode.

One possible cause for non-receipt of a LOFF message will be garbling (overlapping) of messages from two or more transmitters. In this case the controller will ask the pilot to "REPORT LOFF IDENT". This phraseology has been selected because the button on the LOFF control panel (see Figure 4)

which will be used for this function is labelled "REPORT". Activation of this button will cause the LOFF clock circuit to trigger off three LOFF messages at 2-second intervals. Receipt of these three messages will cause the target on the display to change back to the slash symbol, and the data block will flash on and off for several seconds.

Another possible cause for non-receipt is that the aircraft may have departed the VHF coverage of the last repeater station and the pilot has not reset the frequency of his LOFF transmitter to the next repeater station along his route. Occasionally, it may be necessary for the controller to remind the pilot to change to the correct LOFF frequency.

<u>LORAN C Transmitter Failure</u>: Basing LOFF on the use of Loran C in the Gulf region is expected to provide an extremely reliable and fail-soft system. Although the failure of a Loran transmitting station theoretically could affect a much larger geographical area than the failure of a single VOR station, statistics indicate that Loran C reliability is extremely high. Coupled with this is the fact that most Loran C station outages are only momentary in nature; such gaps are bridged automatically by the TDL-711 receiver. Also, the availability of a third secondary station automatically provides a backup in case of prolonged failure of the master station or either of the two secondary stations in the selected triad.

In the event of signal loss from the master, or either of the two selected secondary stations, the TDL 11 goes into a dead-reckoning mode for 15 to 20 seconds.

Normally the interruption is over before that time, in which case the TDL-711 automatically recovers its new Loran C position and resumes normal operation.

If, however, the signal from the lost station is not received by the end of this 15-20 second period, the TDL-711 automatically switches the signal from the backup secondary station into the computer, and converts to the so-called master independent mode. During this conversion period, which lasts 20-30 seconds, the warning flag appears on the CDI and the decimal points light up steadily on the CDU.

When the conversion process is complete the warning flag disappears and the decimal points blink on and off to show that the system is again tracking, but not on the selected triad. In this case the accuracy may be degraded somewhat, especially in terms of what is required for terminal and approach guidance.

Meanwhile the TDL-711 continues to search for the missing signal; as soon as it is re-acquired and tracked, the TDL-711 starts the conversion process back to the selected triad. During this conversion period, which last 20-30 seconds, the warning flag appears on the CDI and the descimal points light up steadily on the CDV.

When this conversion is complete, the flag disappears and the decimal points are turned off to show that the equipment is back in the normal operating mode, on the selected triad.

Loran C Receiver Failure. Precipitation static, which can be a problem to Loran C reception in the Arctic, is not a problem in the Gulf of Mexico region.

If the aircraft is flying on instruments and the Loran C receiver fails, the following backups can be used:

- If the aircraft is still within VOR coverage, the pilot can use VOR navigation back to shore. Although not flight checked beyond 40 nm from the station over oceanic areas, the VOR signals are still available out to about 60nm at helicopter cruising altitudes, and sometimes as far as 80 nm.
- If the pilot is making an ARA approach to a platform, and already has the destination platform positively identified on the airborne radar, he will continue the approach.
- In all other cases the pilot will notify ATC, obtain a hard (exclusive) altitude, and use dead-reckoning navigation until he is back within VOR coverage.

Conclusion

LOFF is designed to do a job that cannot be accomplished with today's system. If the Houston Area tests are successful, an improved system could provide similar advantages in the control of air traffic over much larger volumes of the world's airspace that cannot be covered by conventional ATC surveillance systems.